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The Role of Metaphors in Fostering Macrocognitive Processes in Distributed Teams

Office of Naval Research Grant Final Report for 5/1/2008-4/30/12

Award # N000140810887

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Abstract

This grant project integrated research on team cognition, temporal dynamics, and storytelling towards the goal of improving team coordination and performance in distributed decision making teams. Specifically, the three overall research objectives were: 1) To integrate and empirically investigate multiple types of team cognition/macrocognition (information sharing, team mental models, and situational awareness) to understand their differential effects on team outcomes 2) to infuse a temporal focus into the study of team cognition and team outcomes to better reflect the context of organizational and military teams and 3) to investigate how storytelling (complex form of metaphor) can be used as a team training intervention to improve team cognition and collaboration. Research questions were tested via student teams performing a three-person group task called NeoCITIES, a human-in-the-loop scaled world simulation which is set within the context of emergency management dispatch center. Results provided encouraging evidence that storytelling and reflexivity interventions may help overcome the collaborative obstacles faced by team members in distributed environments, particularly when administered at the group level. Infusing a temporal focus into the study of team cognition and team outcomes proved fruitful in better reflecting the time-based context of many organizational and military teams.

GRANT OVERVIEW

Scientific Objectives and Contributions

This grant project integrated research on team cognition, temporal dynamics, and storytelling towards the goal of improving team coordination and performance in distributed decision making teams. Specifically, the three overall research objectives were: 1) To integrate and empirically investigate multiple types of team cognition/macrocognition (information sharing, team mental models, and situational awareness) to understand their differential effects on team outcomes 2) to infuse a temporal focus into the study of team cognition and team outcomes to better reflect the context of organizational and military teams and 3) to investigate how storytelling (complex form of metaphor) can be used as a team training intervention to improve team cognition and collaboration. This program of research expanded team cognition research into previously unexplored avenues identified as potentially fruitful theoretically, but not investigated empirically. Because failure to understand "when" can seriously jeopardize final team outcomes, we expand the definition of team cognition to include a timework dimension in addition to the traditional teamwork and taskwork content domains. In addition, as storytelling has been under-researched in the team literature, we investigate how the powerful benefits of ad hoc stories can be leveraged as a team training tool to allow team members to get on the same page more efficiently.

Technical Approach

Research questions were tested via student teams performing a three-person group task called NeoCITIES, a human-in-the-loop scaled world simulation which is set within the context of emergency management dispatch center, and designed to emulate a command and control computer communication (C4) environment. NeoCITIES was designed to allow researchers to closely examine team behaviors and monitor the performance outcomes of distributed decision making teams. NeoCITIES methodologically offered a novel, but ideal, interface to investigate multiple aspects of team cognition due to its adaptability, flexibility, and controllability. NeoCITIES allows researchers to trim away the complexities and confounds of a more complex task, in order to hone in on, and test various aspects of team cognition and collaborative decision making.

Within the simulation, teams are made up of three players, who are each assigned to the role of Fire/EMS, Police, or Hazardous Materials (HazMat). Each role is assigned 3 unique resources, each with varying functions. During each game, players were tasked with solving emergency management events by allocating appropriate resources. Scenarios were scripted to require a dynamic environment, high information load, the need to distinguish between relevant and irrelevant information, team member interdependence, and different roles with unique knowledge within the team.

Summary of Study Findings across Four Experiments:

Across studies, results revealed that various types of team cognition impact multiple team performance indices, demonstrating that macrocognition fosters team effectiveness. Several types of team cognition were positively related to team performance, but results differed depending on the type of team cognition (information sharing, shared situation awareness, team mental models) and the team outcome assessed (overall team performance, timing).

Infusing a temporal focus into the study of team cognition and team outcomes proved fruitful in better reflecting the time-based context of many organizational and military teams. Showing promise for future research, temporal team mental models were distinct from taskwork and teamwork categories and added unique variance beyond these traditional measures.

Results provided encouraging evidence that storytelling and reflexivity interventions may help overcome the collaborative obstacles faced by team members in distributed environments, particularly when administered at the group level. Storytelling as an intervention did in fact increase team mental model similarity over a non-story format, which in turn increased team performance. However, storytelling is most useful when a team is additionally given an opportunity to discuss and come to a consensus on the story's meaning while developing strategies to improve future performance. In addition, allowing team members to communally reflect upon their performance and strategies is more effective than individual reflection.

Concise Summary of Accomplishments

To our knowledge, we were the first to empirically examine the effect of planned storytelling as a team training intervention as well as to research the potential additive effects of group reflexivity and individual reflexivity on team mental model similarity. In addition, we pioneered the operationalization of a temporal team mental model.

We conducted four programmatic experimental studies (ranging from 71 to 185 three-person teams in each study) examining the impact of multiple interventions (hidden profile task, storytelling, group reflexivity, individual reflexivity) on multiple macrocognition constructs (information sharing, shared situation awareness, team mental models) and team performance.

We developed NeoCITIES 3.0 and 3.1simulation test beds, which allowed for a higher fidelity scoring model and a modern technological infrastructure that implemented a model view controller framework for modular interface. NeoCITIES 3.0 and 3.1 enabled the empirical investigation of under-researched constructs such as storytelling and temporal mental models as well as integration across macrocognitive concepts such as situational awareness and information sharing.

In terms of output, we produced six publications, fourteen refereed conference presentations, two Master's theses, and one dissertation. One manuscript is currently under review at a peer reviewed journal with several others in preparation for journal submission. These manuscripts are based on the collective sum total of research conducted under this grant. One of the presentations was featured as a top-rated poster at the 2011 Society for Industrial/Organizational Psychology annual conference and a finalist for the best student submission award. The Appendix contains a full listing of grant output.

THEORETICAL BACKGROUND

Research Objectives and Contributions

Increasingly, work is carried out by teams consisting of diverse members who have never interacted previously, but are required to perform complex, dynamic tasks in novel and time-pressurized environments (e.g., Tannenbaum, Mathieu, Salas, & Cohen, 2012). Given the difficulty of this context, the issue of how to enhance team collaboration and performance is increasingly salient in organizational and military settings. Although already a considerable challenge in co-located teams, getting members "on the same cognitive page is even more difficult when team members are geographically separated (e.g., Martins, Gilson, & Maynard, 2004). This grant project integrated research on *team cognition, temporal dynamics*, and *storytelling* towards the goal of improving team coordination and performance in distributed decision making teams. Specifically, the three overall research objectives were:

- *To integrate and empirically investigate multiple types of team cognition/macrocognition (information sharing, team mental models, and situational awareness) to understand their differential effects on team outcomes*

- *To infuse a temporal focus into the study of team cognition and team outcomes to better reflect the context of organizational and military teams*

- *To investigate how storytelling (complex form of metaphor) can be used as a team training intervention to improve team cognition and collaboration*

These research objectives and study results contribute to the team literature in multiple ways. First, learning how various forms of team cognition integratively influence team outcomes has been identified as a critical research need (e.g., Salas & Wildman, 2009; Mohammed, Ferzandi, & Hamilton, 2010). Moreover, empirical work is clearly needed to achieve better understanding of the processes underlying macrocognition and to establish measurement tools (e.g., Fiore, Smith-Jentsch, Salas, Letsky, & Warner, 2010). As such, we empirically investigate information sharing, situation awareness, and team mental models in the same set of studies, allowing for a deeper understanding of their differential effects. Second, as time has been identified as "perhaps the most neglected critical issue" in team research (Kozlowski & Bell, 2003, p. 364) and team cognition measures have been deemed temporally deficient (Mohammed, Tesler, & Mohammed, 2012), we infused time into assessments of information sharing, situational awareness, and team mental models. As such, answer numerous calls to sharpen the temporal lens used in conducting team studies (e.g., Ancona, Goodman, Lawrence, & Tushman, 2001; Mohammed, Hamilton, & Lim, 2009).

Third, because much of the work on storytelling is conceptual (e.g., Denning, 2001), and empirical work has been largely focused at the individual level of analysis (e.g., Ang & Rao, 2008), its applicability in team settings is under-researched. To our knowledge, we are the first to investigate how the powerful benefits of ad hoc stories can be leveraged as a team training tool to allow team members to achieve higher levels of shared understanding and thereby perform more effectively. Fourth, through the integration of team cognition, temporality, and storytelling, we expand these literatures into previously unexplored avenues identified as potentially fruitful theoretically, but not investigated empirically. For example, answer previous research calls to broaden the list of empirically verified antecedents of team mental models (e.g., Mohammed et al., 2010) by examining the effects of storytelling on team cognition. Fifth, beyond these theoretical contributions, NeoCITIES methodologically offers a novel, but ideal, interface to investigate multiple aspects of team cognition because it is easily adaptable and designed to test team cognition and collaborative decision making processes.

Team Cognition & Macrocognition

Team cognition is a general term referencing the collective cognitions of a group (Salas & Fiore, 2004). Over the past decade, the amount of team cognition research has increased substantially across disciplinary boundaries (e.g., Badke-Schuab, Neumann, Lauche, & Mohammed, 2007; Fiore & Salas, 2006; Undre, Sevdalis, Healey, Darzi, & Vincent, 2006). In addition to being identified as one of the hallmarks of expert teams (Salas, Rosen, Burke, Goodwin, & Fiore, 2006), and a recent meta-analysis found that team cognition positively predicted team motivation, processes, and performance (DeChurch & Mesmer-Magnus, 2010).

More recently, the notion of macrocognition has been advocated as a promising mechanism to enable teams to achieve more efficient and effective collaboration. Macrocognition is defined as the "internalized and externalized high-level mental processes employed by teams to create new knowledge during complex, one-of-a-kind, collaborative problem solving" (Letsky & Warner, 2008, p. 7). Macrocognition is viewed as a specific exemplar of the more general area of team cognition research (Fiore, Rosen, Smith-Jentsch, Salas, Letsky, & Warner, 2010). Whereas team cognition has focused on rule-based performance in familiar contexts, macrocognition emphasizes knowledge-based performance in novel situations (Fiore, Rosen et al., 2010). As such, macrocognition was an important theoretical focus of the grant research, which sought to understand and improve team performance in unique, complex, dynamic, and time-sensitive environments.

According to Fiore, Rosen, and colleagues (2010), the team collaborative stages of the macrocognition model include knowledge construction, problem model development, team consensus, and outcome evaluation and revision. Our research especially focuses on the problem model development stage, reflecting how a team arrives at a shared understanding of the problem and viable solutions. In addition, we measure multiple macrocognitive processes, including individual knowledge building, team knowledge building, internalized team knowledge, externalized team knowledge, and team problem solving outcomes. However, our research particularly features team knowledge building and internalized team knowledge in that we measure team information exchange, team knowledge exchange, team mental model similarity and accuracy, as well as shared situation awareness. Team problem solving outcomes are also well represented in our research, as the NeoCITIES simulation has the capability to capture multiple performance metrics that assess the effectiveness as well as the efficiency of chosen solutions.

As both team cognition and macrocognition are broad terms that include specific exemplars, our decision to focus on team situational awareness, temporal mental models, and information shared was based on the current models of macrocognition. For example, components of team knowledge building include information sharing, team situation awareness, and team mental models (Letsky & Warner, 2008; Warner & Letsky, 2008). In addition, the sharing of unique information has been identified as a critical macrocognitive process (McComb, 2008). As such, this project furthers understanding of the processes underlying macrocognition in teams as well as their relationship to other constructs. In addition, these constructs are relevant within the NeoCITIES platform.

Temporal Dynamics & Temporal Team Mental Models

Because increased attention to temporal matters has been identified as a key agenda for future group research (e.g., Eisenhardt, 2004; McGrath & Tschan, 2004), we emphasized multiple dimensions of temporality in the current research. For example, the scenarios within the NeoCITIES simulation were designed to emphasize temporal sequencing and pacing. In addition, as the role of time has been largely downplayed in team cognition research (Mohammed et al., 2012), we add a temporal referent to many of our measures. As we discuss below, special attention was given to expanding the conceptualization of team mental models to include time.

Team mental models are defined as mental representations of the key elements within a team's relevant environment that are both understood and shared across team members (Mohammed & Dumville, 2001). Teams whose members share models of both taskwork (e.g., equipment, performance requirements) and teamwork (interpersonal interaction requirements) domains are better positioned to anticipate the needs and actions of other members, thereby increasing team performance (e.g., Marks, Zaccaro, & Mathieu, 2000; Mathieu, Heffner, Goodwin, Salas, &

Cannon-Bowers, 2000). Researchers from various areas have become increasingly confident that one of the keys to team effectiveness lies within the team mental model (e.g., DeChurch & Mesmer-Magnus, 2010; Mohammed et al., 2010).

Although temporal dynamics clearly play a key role in team mental models, the role of time in both conceptualization and measurement has been largely ignored in existing research. Rather, studies have emphasized task procedures ("what") and team interaction patterns ("how" and "who") (e.g., Mathieu et al., 2000) as two broad categories of mental model content. However, when team members disagree about deadlines and the pace by which tasks should be completed, coordination and performance problems can result. Therefore, establishing and maintaining congruence in team members' temporal perceptions is a non-trivial task. Since failure to understand "when" can seriously jeopardize final team outcomes, we add temporality to the construct of team mental models. Specifically, temporal mental models are defined as agreement among group members concerning deadlines for task completion, the pacing or speed at which activities take place, and the sequencing of tasks (Mohammed et al., 2012). For more information about the conceptual foundation for integrating time and team cognition, see Mohammed et al. (2012).

Metaphors and Storytelling

Given that team cognition and macrocognitive processes facilitate team effectiveness (e.g., DeChurch & Mesmer-Magnus, 2010; Fiore, Rosen et al., 2010), interventions should be developed to enhance the development of shared understanding in teams. As such, we proposed that storytelling (complex form of metaphor), as a powerful means of understanding and structuring reality, will facilitate team members achieving higher levels of shared consensus. Below, we briefly review the literature on metaphors and storytelling.

Metaphors are powerful tools of social constructions that imply "a way of thinking and a way of seeing" (Morgan, 1986, p. 12). A primary purpose of metaphors is to enable us to understand aspects of reality and structure behavior (Stutman & Putnam, 1994). By analogical extension, metaphors carry ideas from one domain to another in which the ideas are not immediately applicable (Black, 1962). Sensemaking is enhanced by comparing new concepts that have not been directly or indirectly experienced to what is already known. Metaphors play an important role in surfacing tensions and ambiguities inherent in constructs. In addition to altering perceptions, metaphors also structure behavior. By improving understanding regarding an unknown and unfamiliar phenomenon, metaphors shape future actions (Schultz & Orlikowski, 2001).

Categories of metaphors include spatial (capture a direction that is typically associated with positive and negative attributions), ontological (utilize concrete substances or objects to describe abstract experiences like states and emotions), metonymy (capture the whole in terms of a constitutive part), personification (apply human traits to inanimate objects), and structural (match structural requirements of the phenomenon with those of the metaphor) (Lakoff & Johnson, 1980). Numerous examples of the use of metaphor can be found in psychological and organizational literatures. For example, organizations have been described in terms of machines, organisms, and brains (Morgan, 1986). In identifying several overarching metaphors of virtuality, Schultz & Orlikowski (2001) described virtual organization as platform (architecture), space (location), bits (resource), community (governance), and a network of relationships (identity). In addition, metaphor has been used extensively in group therapy (e.g., Sunderland, 1997) and to describe group process (e.g., Cowell, 1972).

Because they transfer meaning across conceptual domains, metaphors are especially valuable when exploring complex, novel, and poorly understood phenomena (Klagge, 1997). According to Lakoff and Johnson (1980), metaphors are "one of the most important tools for trying to comprehend partially what cannot be comprehended totally" (p. 193). In addition, metaphors play a critical role in early stages of theory development, before specific hypotheses are articulated (Conrnelissen, 2005). Given the complexity of macrocognitive processes as well as its formative stage of research development, examining the role of metaphors in enabling teams to get on the same cognitive page more efficiently and effectively is particularly timely.

As a more complex version of metaphors, storytelling is one of the oldest methods for communicating knowledge across people (e.g., Bal, 1997; Denning, 2001). The purpose of a story or narrative is to convey complicated ideas in an intriguing and clearly understood manner (e.g., Klein, 1998). Several authors have proposed that storytelling can improve team learning and performance (e.g., Bartel & Garud, 2009; Denning, 2001; Fiore et al., 2009). For example, Fiore, McDaniel, and Jentsch (2009) state that "stories can be a form of contextual glue that becomes the basis for an ensuing dialogue as teams evolve over space and time in information spaces mediated by both virtual and physical cues." We explored the use of storytelling as a planned team training tool because storytelling has been proposed to be effective in distributed teams (Fiore et al., 2009), but not empirically verified. Given that storytelling may be especially valuable when exploring complex, novel, and poorly understood phenomena, it may prove especially useful in aiding geographically distributed members to achieve shared understanding. For more information about storytelling as a training intervention, see Mancuso, Parr, McMillan, Tesler, McNeese, Hamilton, & Mohammed (2011), Tesler, Mohammed, Hamilton, Mancuso, Parr, MacMillan, & McNeese (2011), and Tesler, Mohammed, Mancuso, Hamilton, & McNeese (2012).

THE NeoCITIES TEAM SIMULATION

NeoCITIES is a human-in-the-loop scaled world simulation designed to allow researchers to closely examine team behaviors and monitor the performance outcomes of spatially distributed decision-making teams (McNeese, Bains, Brewer, Brown, Connors, Jefferson, Jones & Terrell, 2005). Abstracted from the original CITIES task (Wellens & Ergener, 1988), NeoCITIES uses information processing theories and knowledge elicitation research (Wellens & Ergener, 1988) to examine the role of cognitive processes in facilitating knowledge acquisition and transfer (McNeese, 2000). NeoCITIES features team resource allocation problems designed to emulate crisis management of a city's emergency services in a virtual environment. In the early stages of its creation, realistic scenarios were developed from interviews with intelligence analysts and fieldwork in emergency crisis centers (McNeese et al., 2005).

The newest versions of NeoCITIES (3.0 and 3.1) are web-based applications based on instant chat technology and an interactive interface. Three person teams play the roles of police, fire/EMS, and hazardous materials (hazmat). Each unit is responsible for different resources. For example, the fire unit has ambulances, fire investigators, and trucks at their disposal. Team members are tasked with dispatching the relevant type and number of resources to emergency management events that arise. When faced with a new scenario, participants must decide the severity of incoming events, what resources are needed, and how many resources are needed, and whether assistance is required of other team members. NeoCITIES allows for both qualitative (chat logs) and quantitative (performance scores and other behavioral metrics) data collection. For more information about the NeoCITIES simulation, refer to Hellar & McNeese (2010) and Hamilton, Mancuso, Minotra, Hoult, Mohammed, Parr, Dubey, MacMillan & McNeese (2010).

Rationale for Selecting NeoCITIES

There are several reasons why NeoCITIES is well suited to test the research objectives articulated above. First, it is designed to test team collaborative decision making process, knowledge acquisition and knowledge management within a command and control computer-mediated communication environment. As such, it is the ideal interface to investigate macrocognitive processes such as information sharing, shared situation awareness, and team mental models. Second, emergency crisis management offers an excellent real world domain in which meets the requirements of a complex system articulated by Rouse, Cannon-Bowers, & Salas (1992), including a highly emergent, dynamic, and complex environment, ambiguous and uncertain information, as well as individuals with differing roles needing to interact and share information as a team. Third, as an adaptable interface, NeoCITIES can be scripted to represent routine (e.g., law enforcement) and non-routine (e.g., terrorism) scenarios ranging from individual events to highly interdependent occurrences that escalate when resources are not properly allocated. Therefore, the simulation is scalable and flexible enough to accommodate the new scenario development that was needed to test research questions involving macrocognition, temporality, and storytelling. Fourth, objective dependent variables are easily collected, including team performance (quantitative score indicating overall progress), time to decision, decision errors, and number of failed events. Fifth, participants find NeoCITIES to be an engaging, realistic exercise which maintains interest and high levels of student participation.

The NeoCITIES 3.1 User Interface

The NeoCITIES 3.1 interface is made up of five primary components: the chat panel, the dispatch panel, the team monitor, the unit monitor, and the event tracker (see Figure 1). The chat panel (A) allows users to communicate and coordinate with each other. The chat panel is a necessary feature in the interface because several of the events in NeoCITIES 3.1 require coordination among the various roles in the simulation. The dispatch panel (B) indicates which resources are currently available. To dispatch resources, the user drags the desired resources into a box and presses a dispatch button. The resources are then dispatched to the selected event and are no longer available. Resources are returned to the dispatch panel when an event completes or a resource is recalled. The team monitor (C) provides information on the event the participant's teammates are currently working, along with the type and number of resources available to them. This information is useful for helping team members collaborate and coordinate with each other. The unit monitor (D) provides participants with information on their units' status and location. The unit monitor also provides feedback reports on the events to which the participant has responded. The reports indicate whether or not the unit was able to help with a specific event and whether more resources are needed. The participant may recall a resource if it is unable to help resolve an event. The event tracker (E) is divided into two parts: a list of current events and a list of closed events on which no more action may be taken. In this section, participants can see the name, description, status, and severity of current events. The tracker is also used to select the events to which resources are dispatched.

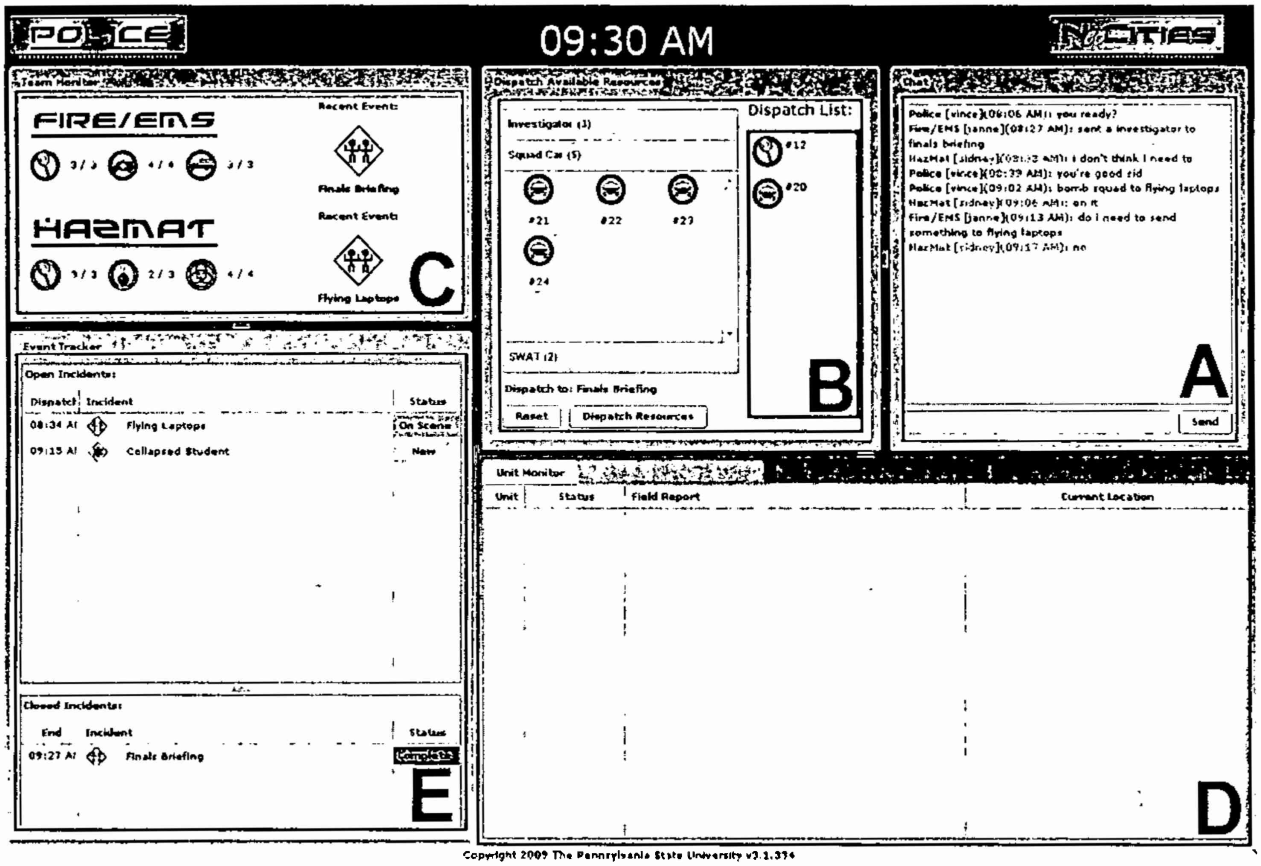

Figure 1: The NeoCITIES 3.1 User Interface
A= Chat Panel; B=Dispatch Panel; C=Team Monitor; D=Unit Monitor; E=Event Tracker

Improvements in NeoCITIES over Years 1-3 of the Grant

The methodological focus of the first year of the grant was the development of NeoCITIES 3.0 and the set up of the client server architecture, which was under construction for more than nine months, requiring over 10,000 lines of code and over a month of pilot testing the new interface. As this simulation was the platform upon which all of our experiments were conducted, the time needed to complete the development and piloting of NeoCITIES was a worthy investment to ensure ecological and internal validity.

NeoCITIES 3.0 was built using Web 2.0 technologies, and was designed as a more flexible research tool and to have a more powerful graphical human-computer interface. Specifically, NeoCITIES 3.0 allowed for a higher fidelity scoring model, data logging, and a modern technological infrastructure that implemented a model view controller framework for modular interface. In addition, it allowed for an adaptive interface that was scalable and flexible enough to accommodate new scenario development. Figure 2 shows a screenshot of the NeoCITIES 3.0 interface.

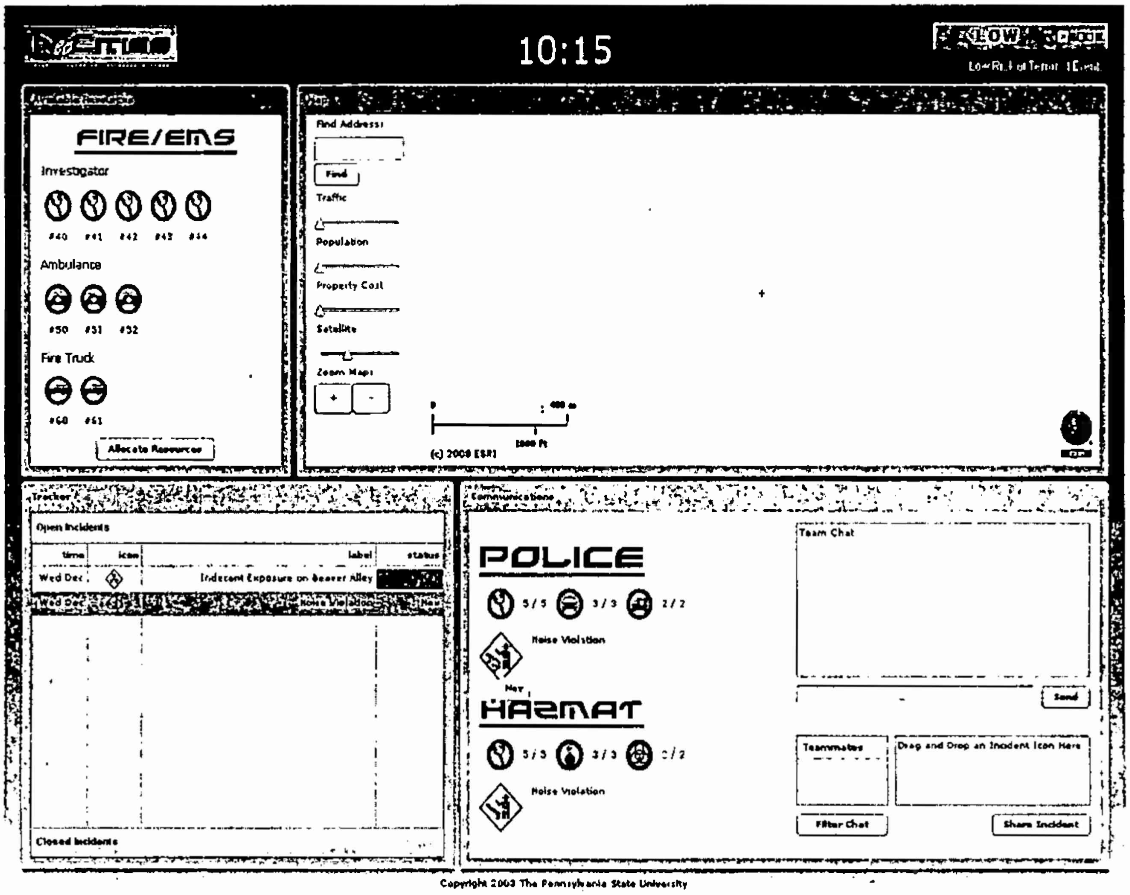

Figure 2: The NeoCITIES 3.0 User Interface

In the second year of the grant (in preparation for Studies 2 and 3), further refinements to NeoCITIES were made to upgrade the interface and add new data collection mechanisms, resulting in the most recent 3.1 version. For example, we created a video-based training (auditory as well as visual) to introduce more experimental control over the self-paced PowerPoint slides (text-based only) utilized in the first study. On the server, we improved score reporting by building the capability to log more rich behavior metrics, including reaction times, communication patterns, and order, to name a few. On the client computers, time was changed to a 12-hour format rather than the timer format used previously. Given the importance of temporality in our studies, this was an important and needed change. In addition, time stamps were added on the chat messages, which helped with coding chat logs. Furthermore, if the experimenter had already "initialized" the game and the player loaded up their screen late, it would direct them to the login screen.

Based on the analysis of data in the first three studies, several modifications again were made to the NeoCITIES simulation in the third year of the grant (in preparation for Study 4). For example, the interface was reorganized to allow for easier participant navigation and clarity, as shown in Figure 3. Measures that were previously in paper and pencil form were transferred to an online format within NeoCITIES, including SAGAT (freeze-probe measure of situational awareness) and information briefings. Improvements were also made to the team mental model measures. Significant time was also invested in altering the simulation scenarios to enhance the temporal performance measures in the game.

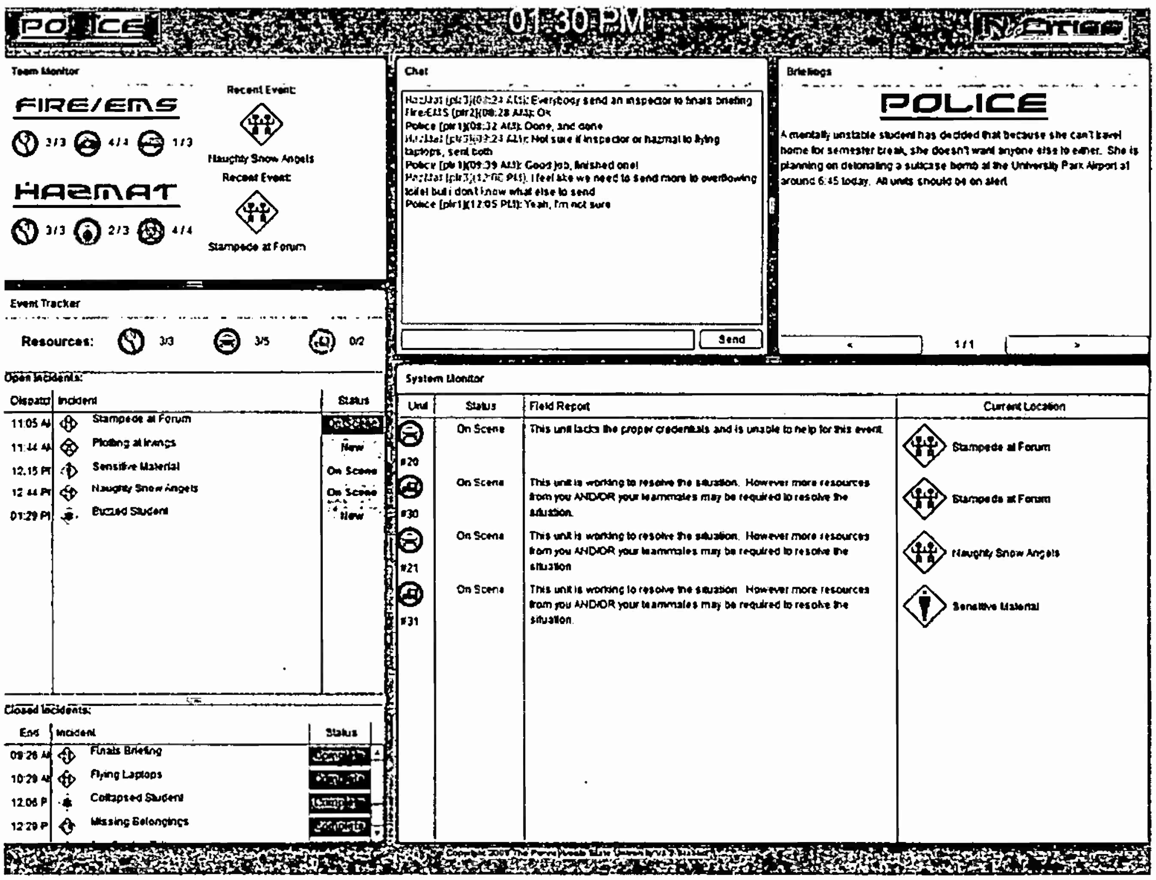

Figure 3: Modifications to the NeoCITIES User Interface Used in Study 4

Table 1 summarizes the history of the NeoCITIES simulation. For additional information about the development of NeoCITIES in comparison to other simulations, see McNeese and Pfaff (2012).

Previous Versions	**NeoCITIES 1.0 (2004)**	The original JAVA C2 Simulation. Informed by original CITIES Simulation and Ethnographic research of emergency management Officials. Used to study, intelligent group interfaces, Fuzzy Cognitive maps, and Stress and Mood
	NeoCITIES 2.0 (2006)	Updated version of NeoCITIES 1.0 that was redesigned using Web technologies, and with greater emphasis on Geographic Information Systems. Used to study Geo-Collaboration
Current Versions	**NeoCITIES 3.0 (2008)**	Addressed the limitations of previous versions, simplified role structure, added new capabilities, designed new interface. Used to study Information overload, situation awareness, information sharing, team mental models, and storytelling.
	NeoCITIES 3.1 (2009)	Updated version of 3.0 with greater emphasis on mechanisms to study information sharing, team mental models, and situation awareness. Improved user interface. Used for similar purposes as 3.0
Future	**Continue to iterate on current version and design new versions to test future theories and propositions of macrocognition.**	

Table 1: Summary of the History of the NeoCITIES simulation

Scenario Development in NeoCITIES

In addition to the effort required to build the NeoCITIES simulation, creating the scenarios within the simulation required a large investment of time, thought, and creativity. Emergency events were scripted around the university campus to increase realism and relevance to student participants (e.g., student rioting, bomb threats during exams, intoxication, apartment fires, and fumes from the chemistry building). For studies 1-3, the first scenario involved a football theme, and the second scenario involved a finals exam week theme. For study 4, the second scenario was altered to remove some complexity involving hidden profile information, based on piloting feedback and little performance variability on certain events. Events varied in their severity (e.g., trash can fire versus a chemical tanker truck collision).

Scenarios were written to require a dynamic environment, high information load, the need to distinguish between relevant and irrelevant information, and different roles with unique knowledge within the team. Some events were independent in that they only required resources from one unit (e.g., only EMS was required to revive a collapsed student suffering from dehydration). However, other events were interdependent in that they required resources from multiple roles (e.g., police, fire, and hazmat units were needed to respond to a large fire that may have been chemically induced and involved the possibility of arson). Some interdependent events required a response from two units and others required all three. Additionally, temporal requirements were infused in scenarios by prescribing that teammates respond on the scene of events within a particular time frame or in a certain sequence (e.g., Police first, fire/EMS second, and hazmat third). In the third year of the grant (in preparation for Study 4), simulation scenarios were rewritten and piloted to improve temporal measurement in the game.

DESCRIPTION OF PROCEDURES AND MEASURES COMMON ACROSS ALL FOUR EXPERIMENTS

Laboratory Set-Up

Data collection necessitated the set-up of two parallel laboratory infrastructures in psychology as well as information sciences and technology. In each lab, six separate computers were isolated from each other via dividers to mimic distributed teams. Three computer stations were in a row on one side, with another three computer stations across from the first row on the other side. Therefore, each lab could run two 3-person teams through the NeoCITIES simulation at one time. There were also two server computers used by experimenters at the front of the first two rows.

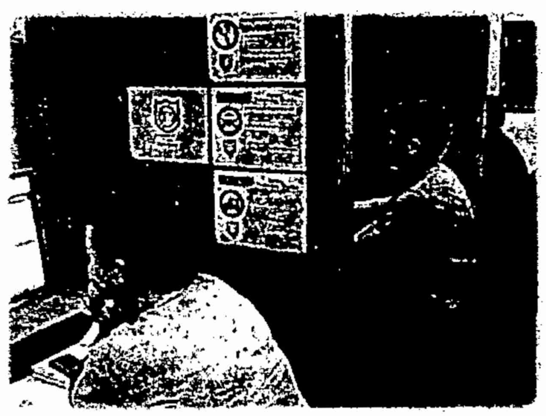

Figure 4: Pictures of the Psychology and Information Science and Technology Data Collection Labs

Participants

Student participants were obtained from undergraduate information sciences, psychology, business, and human development classes as well as the psychology subject pool. Students received course or extra credit for their participation.

General Experimental Procedure

After random assignment to a three-person team and a member role (Police, Hazmat, or Fire/EMS), students were first trained on the mechanics of playing the NeoCITIES simulation. This training covered how to review event descriptions and allocate resources to events and was followed by a practice scenario including only independent events. Students were also trained on the team dynamics within the simulation, which was also followed by a practice scenario including both independent and interdependent events. In the training, the number of events as well as the complexity of informational content increased over the two trainings. After each training session, participants received a computer generated team performance score and had the opportunity to review the solutions to each event.

Following the training, students completed two NeoCITIES performance scenarios, each of which was 14-15 minutes in length. During each performance session, participants received one or two information briefings containing data that was useful in resolving key events in the scenario. In addition, the NeoCITIES simulation was paused once during each performance scenario to allow participants to complete a measure of situation awareness. At the end of each scenario, students were provided with computer generated team performance scores. Throughout the study, online as well as paper and pencil measures were collected. Participants generally found the NeoCITIES simulation engaging and reported that it held their interest.

Each study was preceded by extensive piloting with undergraduate research assistants as well as subject pool students. Piloting involved checking the technical features of NeoCITIES, the clarity of the training materials, the difficulty of scripted events, the timing of the study, and the variability in responses to measures. In addition, several adjustments were needed to ensure that manipulation checks and measures were effective, and modifications were re-piloted before formal data collection commenced.

Dependent Measures

Dependent variables were information sharing, shared situation awareness, team mental models, and team performance. The measurement of each will be described briefly below.

Information sharing was measured qualitatively via coding communication chat logs recorded during the simulation. Therefore, NeoCITIES allowed for a rich and more objective indicator of information sharing than self-report measures. Undergraduate research assistants were trained to code for information sharing on interdependent events regarding resources required (e.g., "Police should go to Tanker"), order ("It's Hazmat, fire, then me for Tanker"), pacing ("You have to respond to the bank in under 45 seconds"), and deadlines ("Ohio State fans defacing South Atherton at 6:30 today"), as well as other categories. At least two research assistants coded each set of chat log transcripts, and interrater reliability was adequate (typically above .7).

Shared situation awareness refers to a shared perspective regarding current environmental events (Wellens, 1993). It is comprised of three levels (Endsley, 1995a). Level 1 (perception) reflects the degree to which individuals perceive temporal and spatial elements of events in the environment (e.g., a pilot noticing an image on a radar screen). Level 2 (comprehension) references the extent to which individuals understand the meaning of these events (e.g., understanding that the image represents an approaching aircraft). Level 3 (projection) captures the degree to which individuals use these details on events to predict their status in the near future (e.g., planes will crash in one minute if courses are not corrected; Endsley, 1995a).

Shared situation awareness was assessed using three different metrics, one of which was an objective indicator (e.g., Situation Awareness Global Awareness Technique; SAGAT) and two of which were subjective indicators (adaptations of the Mission Awareness Rating Scale (MARS; Matthew & Beal, 2002) and the Situational Awareness Rating Technique (SART, Taylor, 1990)). As the most popular and validated measure of situation awareness (Endsley, 1995b), SAGAT is a freeze probe technique that requires the task to be randomly stopped in order to ask participants a series of questions regarding their perceptions of the current situation. NeoCITIES and scenario sequencing had to be modified to integrate the SAGAT freeze into the simulation so that participants would not be able to predict and prepare for its occurrence. The SAGAT measure consisted of ten multiple choice and short answer questions based on simulation events (e.g., Based on the event description, what would MOST likely happen if units didn't arrive on scene within 60 seconds in the case of tanker collision?). There was only one correct answer for each question that could be verified based on scenario scripting and a detailed action history of participant responses.

In contrast to SAGAT, which was measured during NeoCITIES scenarios, MARS and SART were administered after participants had played the simulation. In addition, whereas the SAGAT questions had to be tailored to NeoCITIES, MARS and SART were generalized measures that could be used in a variety of contexts. Adapted from Matthew and Beal (2002), the MARS measure was derived from the most popular self-report measure of *team* situation awareness (the Crew Awareness Rating Scale, CARS; McGuinness & Foy, 2000) for use in non-military settings. MARS consisted of five items rated on a four-point behaviorally anchored rating scale. A sample measure is, "Please indicate your team's ability to identify changes in events (e.g., pacing, complexity) throughout the scenario." On the other hand, SART was adapted from Taylor (1990), and is considered to be the most popular self-report measure of *individual* situation awareness (Salmon, Stanton, Walker, & Green, 2006). SART was assessed via seven items measuring perceptions of elements in the team's work environment on a seven-point scale. A sample item is, "The unpredictability of the events received in the scenario." SAGAT; MARS, and SART measures were collected at two separate time points within the span of the NeoCITIES experiments.

Team mental models capture members' shared, organized understanding and mental representation of relevant team knowledge (Mohammed & Dumville, 2001). Two properties of team mental models are sharedness (the degree to which members' mental models are consistent with one another) and accuracy (the degree to which members' mental models converge with experts' mental models; Mohammed & Hamilton, 2012).

Three different types of team mental model content were measured: team (how and with whom work gets done), task (what work gets done), and temporal (when work gets done). All three types were assessed using paired comparison ratings, one of the most popular measurement techniques (Mohammed et al., 2010). Each mental model contained a list of six dimensions that were generated through careful analysis of the task requirements, collaborative processes, and temporal dynamics involved in NeoCITIES. The six dimensions were briefly defined and arranged into a 6 X 5 grid. Participants were asked to rate the similarity of each dimension on a scale of 1 (extremely unrelated) to 5 (extremely related). Sharedness was assed using QAP correlations (e.g., Mathieu et al., 2000). Accuracy was based on the taskwork, teamwork, and temporal team mental model ratings of three subject matter experts, which correlated at .70 or higher before discussion. Discrepancies among ratings were discussed until consensus was reached. The average sharedness of teams with the expert ratings was assessed using QAP correlations (e.g., Mathieu et al., 2000).

In addition to paired comparison ratings, temporal team mental models were also assessed via concept mapping, another common assessment technique used in the literature (e.g., Mohammed et al., 2012). After each performance session, participants were given a list of three events and asked who should arrive to the event first, second, and third. Trained coders evaluated the similarity among team member maps and the number of direct links shared in Studies 1 and 2. Agreement ratings were .70 or higher. Concept map accuracy was based on the number of roles accurately placed in each sequence. For further information on team mental model metrics within NeoCITIES, refer to Mancuso, Hamilton, McMillan, Tesler, Mohammed, & McNeese (2011).

To learn more about how information sharing, team situation awareness and team mental models were measured within the NeoCITIES context, see Hamilton et al. 2010.

Team performance was operationalized objectively through the scores generated by the NeoCITIES simulation. The overall team performance score was calculated based on an event growth formula that accounted for the number of events, severity of events, and the time taken to successfully resolve events. As such, task performance in NeoCITIES rewards players that quickly and correctly allocate the correct number and type of resources to an event. Players receive lower scores when opportunities are lost through inaction or slow and/or incorrect responses. In addition to the overall team performance score, NeoCITIES was also modified to provide more circumscribed performance scores for temporally infused events, independent events, and interdependent events. For more information about NeoCITIES performance metrics, see Hellar (2009) and Hellar and McNeese (2010).

Complexity of Data Collection and Analysis

It should be noted that many of the team cognition measures that we assessed are context-dependent and therefore had to be developed specifically for the NeoCITIES simulation (e.g., information sharing coding; task, team, and temporal team mental model paired comparison ratings and concept maps; SAGAT). In addition, several parts of data management and analysis required coding. For example temporal mental models measured through concept maps were coded for the number of direct links shared among team members as well as for accuracy. In addition, each chat log was coded by multiple students according to a detailed coding rubric. Determining the coding template, piloting the template, and coordinating the actual coding required substantial time and effort.

For all analyses, the unit of analysis was the team. The following bullet points reflect the complexity of the data analysis:

- Complex coding required to capture information sharing from chat logs across 6 categories (measured twice in each study)
- 3 types of team mental models (taskwork, teamwork, temporal)
- 2 properties of team mental models (similarity & accuracy)
- 2 operationalizations of team mental models
    - Concept maps required coding (measured twice in each study)
    - Paired comparison ratings translated into QAP correlations
- 3 operationalizations of situation awareness (measured twice in each study)
- Various measures of team performance (measured twice in each study)

After briefly reviewing the purpose and specific methodologies of the four experimental studies, the results will be presented below.

STUDY 1

Objectives and Overview

The objectives of Study 1 were to empirically investigate multiple macrocognitive processes in a single study, to infuse macrocognition measures with a temporal focus, and to operationalize the notion of a temporal team mental model. Specifically, this study manipulated the degree of sharing of temporal information among participants (unique versus shared) and examined the impact of this hidden profile task on information sharing, shared situational awareness, temporal mental models, and team performance. It was expected that a shared information profile would positively impact these forms of macrocognition.

In Study 1, the following model was tested:

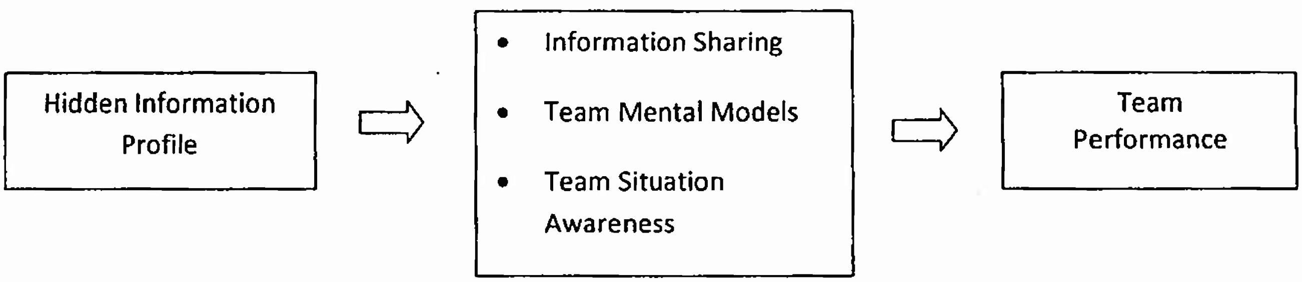

Figure 5: Study 1 Model

Participants and Procedure

The sample for Study 1 consisted of 216 psychology undergraduates (139 females (66.8%) and 69 males (33.2%)). Students were divided into 72 three-person teams (37 shared condition and 35 unique condition). Participants reported a high level of engagement in playing NeoCITIES (Mean = 4.08/5.00). The study took two hours to complete.

The experimental procedure consisted of the following steps:

- Online Survey 1
- Basic NeoCITIES Training via PowerPoint slides
    - 7 minute practice scenario on independent events
- Team Training via PowerPoint slides
    - 6 minute practice scenario on interdependent events
- Online Survey 2
- Performance Scenario 1 (14 minutes)
    - SAGAT freeze, 1 information briefing (shared or unique condition)

- Online Survey 3
- Performance Scenario 2 (15 minutes)
    - SAGAT freeze, 2 information briefings (shared or unique condition)
- Online Survey 4 and Written Survey

Information Sharing Manipulation

The degree of information sharing among participants was manipulated through information briefings delivered to participants at specified times to coincide with events dispatched throughout the simulation. Briefings contained temporal information about deadlines (attack expected at 6:30), pacing (all units need to arrive on scene in 30 seconds of simulated time), and/or ordering (police should arrive first, then fire). Teams were randomly assigned to either the unique (only one team member received the information) or shared (multiple team members received the information) condition.

Results

As expected, the shared hidden profile condition resulted in increased overall information sharing at Time 1 and 2. Also as predicted, teams in the shared information condition had higher shared temporal team mental models than those teams that received unique information. These effects occurred for both similarity ratings ($t\ (62) = 2.40$, $p < .05$) and concept maps ($t\ (63) = 1.87$, $p = .067$), but was only marginally significant for the latter. These results suggest that the positive effects of open information sharing on team performance (Mesmer-Magnus & DeChurch, 2009) may take place through team mental model sharedness. Furthermore, the shared information condition was associated with a higher order performance score at Time 2.

Hierarchical regression analyses revealed that macrocognitive processes had differential effects on various forms of team performance. As measured by coded chat logs, higher overall information sharing resulted in higher team performance on timed events at Time 1 and 2. Higher concept map similarity resulted in increased order performance at Times 1 and 2 and increased overall, pacing, and interdependent team performance at Time 2. Higher teamwork similarity ratings resulted in increased overall and interdependent team performance at Time 2. Higher temporal similarity ratings increased the pacing score at Time 2 (marginal significance). Regarding situational awareness, results showed differential prediction across all three measures, such that SART was positively predictive of individual performance, whereas team-level SAGAT and MARS were surprisingly positively predictive of both individual and team performance. Higher scores on MARS and SART were also associated with higher engagement in team processes and satisfaction.

Temporal team mental models were not significantly correlated with teamwork or taskwork team mental models. The relationships between temporal team mental models measured through concept maps and those measured through paired comparison ratings had distinct effects on team performance for temporal events. Temporal team mental models had a positive, significant relationship with team performance when assessed via concept maps, but not when assessed via similarity ratings. Consistent with these results, a recent meta-analysis concluded that the effects of team mental models on performance vary according to the type of measure used to evaluate the construct (DeChurch & Mesmer-Magnus, 2010b).

Conclusions

As hypothesized, a shared information profile positively impacted various forms of macrocognition. Moreover, results revealed that team cognition matters for team performance. Several types of team cognition were positively related to team performance, but there was a differential pattern of results in that information sharing and temporal mental models were more positively related to timing performance metrics whereas shared situation awareness was more positively related to overall team performance and a broader range of performance indicators. These results contribute to the team literature because understanding the differential effects of multiple forms of team cognition has been identified as a key research need (e.g., Mohammed et al., 2010; Salas & Wildman, 2009). In addition, team cognition assessment methods have been temporally deficient (Mohammed et al., 2012).

Temporal mental models were found to show a distinct pattern of results from more traditional team mental model content. Specifically, temporal mental models exhibited a different pattern with team performance than teamwork mental models. High performing teams had *both* high sharedness and accuracy of temporal mental models, but *either* high sharedness or accuracy of teamwork mental models. Future work should further examine the role of temporal mental models as a new content domain given that it was non-redundant with more traditional forms of mental models in this study. As failure to agree on how temporal resources should be allocated among team members can seriously jeopardize team outcomes, the conceptualization and operationalization of a temporal team mental model demonstrates promise for future research.

STUDY 2

Objectives and Research Questions

The objectives of Study 2 were the conceptualization and operationalization of storytelling as a complex form of metaphor and to explore the use of storytelling as a team training tool. Specifically, we examined the influence of four types of stories and a control group (no story) on information sharing, team mental models, and team performance. In terms of research questions, we explored whether storytelling, as a team training intervention, improves information sharing, team mental models, situation awareness, and team performance. In addition, we investigated whether different types of storytelling differentially affect outcomes. For example, collaboration stories may be more likely to influence teamwork mental model sharedness and accuracy, whereas timing stories would be more likely to influence temporal mental model sharedness and accuracy.

Story Development

We first conducted a review of the literature on metaphors. Given the disconnect between the types of metaphors discussed in the literature and what would be relevant in a simulated emergency management context, we turned to storytelling, a more complex version of metaphors. We conducted a literature review on the storytelling literature and consulted with Steve Fiore, who provided us with several of his relevant papers on the intersection of narrative and distributed teams. Although Fiore's work provided us with an excellent conceptual framework for integrating storytelling and teams, the lack of empirical work in this area meant that we had little guidance in writing stories that would work in a team simulation context and developing measures to test their effectiveness. Our research team spent many hours brainstorming to come up with ideas for the content of the stories (sports context, design teams) as well as discussing the logistics of the story medium (e.g., written, auditory, illustrated). It took several months of planning before we decided, after much discussion and deliberation, on the four stories described below.

Story Content: Collaboration and Timing. Metaphors play an important role in surfacing tensions and ambiguities inherent in constructs. As metaphors are especially valuable when exploring complex, novel, and poorly understood phenomena, we identified areas of the experiment and the NeoCITIES interface where students commonly experienced confusion and were in need of further instruction. Based on observations and qualitative, self-report data from Study1, two participant problem areas important to success in the NeoCITIES simulation were virtual collaboration across units (police, fire, hazmat) and temporal sequencing (which units should arrive first, second, and third). Therefore, we directed our efforts toward story creation in these areas that were relevant within an emergency management context. The collaboration theme highlighted the breakdowns that occur when teams fail to communicate critical information, and the timing theme highlighted the breakdowns that occur when teams fail to attend to the pacing and ordering of member actions

Story Context: Metaphorical versus Analog Stories. In addition to the story content, decisions had to be made concerning story context. One view is that sensemaking is enhanced by comparing new concepts that have not been directly or indirectly experienced to what is already known. In this line of thinking, if a metaphor's content is familiar to the listener and couched in a story to increase listener engagement, then any metaphor presented within the framework of a narrative could potentially invoke learning (e.g., Gilman & Gillan, 2001). Therefore the term "metaphorical storytelling" is used to refer to stories that help to connect what listeners are less familiar with to what they are more familiar with. Since stories should be relatable (Denning, 2001) and popular TV shows have popularized this setting, the metaphorical story occurred in a medical context. The medical/metaphorical story was based on a true story that occurred at a hospital in New York City. In the story, the protagonist breaks his leg during a winter vacation. The patient's post-surgery recovery encountered complications that stemmed from collaboration and timing errors of the medical team.

In contrast to metaphorical storytelling, analog storytelling maintains a closer connection between the story and the target domain. Derived from analogical problem solving (Bransford & Stein, 1984), the goal of analog storytelling is to apply the principles of narrative to a domain to a similar situation that the story represents. The NeoCITIES/analog story focused on a graduate student working in a laboratory environment during a severe snowstorm. During an unforeseen power outage, the protagonist has an accident where a beaker of acid he was carrying splashed its contents on his left arm. The character has severe chemical burns and requires the assistance of police, fire, and hazmat. Complications stem from collaboration and timing errors of the response team.

Analog storytelling may be more effective than metaphorical storytelling in that the conceptual leap between the story and the target domain is smaller, allowing participants to more easily see the connections. In contrast, metaphorical storytelling may prove superior to analog storytelling because of its greater versatility and its ability to link a domain that is more familiar with a domain that is less familiar to participants.

Deep versus surface-level structure. Before writing the stories, we first had to identify the deep structural elements of NeoCITIES to ensure that the stories had parallels to the simulation that could improve the user's performance. NeoCITIES subject matter experts listed several deep structure elements, including three distinct roles, team monitor, overt communication between roles, and sequencing. With the medical/metaphorical story, the deep level structure was similar to NeoCITIES, but the surface level structure was distinct. On the other hand, both surface and deep structure were similar to the simulation for the NeoCITIES/analog story.

The process of story construction. Our stories were designed to embed the deep structure about the NeoCITIES simulation into an engaging and applicable story format using the principles of narrative. Each of the four stories went through several drafts, informed by internal discussions among the research team as well as sources with medical expertise (for the medical stories) and emergency crisis management experience (for the NeoCITIES stories). We had to balance the need to incorporate the deep level structure of collaboration and timing requirements in the NeoCITIES simulation with the need for the story to be realistic, credible, and engaging. We consulted with a professor and writer from the English department to edit our stories and ensure that they met the principles of narrative.

Several pilot studies were conducted to refine the stories and test participants' reactions. After conducting informal pilots with undergraduate research assistants, we conducted a formal pilot study with participants from the subject pool. Based on the valuable feedback provided from all of these sources, we successively revised the stories as well as the power point illustrations. In order to introduce more experimental control, we felt that it was important for the stories to be audio-recorded and accompanied by pictures illustrating the major points on PowerPoint slides that were synchronized to the audio recording. In piloting, students reacted positively to this storytelling format. Thus, with successive edits, the stories had to be re-recorded and timed with power point slides many times throughout the course of the semester. In addition to participant feedback with regard to realism, credibility, interest level, and affect, we also needed to ensure that the four stories were similar in length and structure. For more information about how the stories were constructed, see Mancuso, Parr et al. (2011).

Storytelling Manipulation

Four types of stories (medical timing, medical collaboration, NeoCITIES timing, and NeoCITIES collaboration) and a control group (no story) were constructed. The four stories allowed us to test the effect of story content (timing versus collaboration) as well as story context (medical versus emergency crisis management) on macrocognitive processes. In the medical context, the deep level structure was similar to NeoCITIES, but the surface level structure was distinct (metaphorical storytelling). In contrast, in the NeoCITIES context, the surface and deep level structures were similar (analog storytelling). Each story was approximately four and a half minutes in length.

In the control condition, participants were given a description of a college EMS service in a factual form that did not meet the requirements of a story. The description was written to be of similar length as the four stories and had a similar surface structure (emergency response) to NeoCITIES. However, unlike the stories, it did not have deep structure nor incorporate the principles of narrative.

Participants

Participants consisted of 294 individuals (52% Male, 47.1% female) divided into 98 three-person teams. The sample was 78.2 percent Caucasian, 52.9 percent male, and 41.0 percent junior students. The average age of the sample was 20.54 (SD = 1.39). On a scale of 1 (none) to 5 (extensive), participants reported having little to moderate levels of experience working in a virtual team (mean = 2.23, SD = 0.81).

The five story conditions were roughly equal in terms of team sample size:

- 4 story conditions:
    - Medical Collaboration (n=18)
    - Medical Timing (n=19)
    - NeoCITIES Collaboration (n=20)
    - NeoCITIES Timing (n=19)
- Control condition (n=22)

Experimental Procedure

The experimental procedure consisted of the following steps:

- Basic NeoCITIES Training Video
    - 5 minute practice scenario on independent events
- Team Training Video
- Storytelling Video (4.5 minutes)
    - Online manipulation check
    - 5 minute practice scenario on interdependent events
- Performance Scenario 1 (14 minutes)
    - SAGAT freeze, 1 information briefing
- Online Survey
- Performance Scenario 2 (15 minutes)
    - SAGAT freeze, 2 information briefings
- Written and online surveys

In addition to the storytelling manipulation, Study 2 differed from Study 1 in that only unique information briefings were distributed (only one participant received each piece of information). In addition, the experiment schedule had to be lengthened from 2 to 2 and ½ hours. We also moved to video-based training, which was an improvement over the PowerPoint slides used in Study 1. Thus, we introduced increased technical demands with the storytelling study beyond the challenges associated with running the basic NeoCITIES simulation.

Results

The storytelling manipulation checks were generally effective. Participants in the collaboration conditions reported that the stories reflected more communication than timing. Participants in the timing conditions reported that the stories reflected both timing and collaboration. Given that sequencing encompassed both collaboration and timing, the latter finding is not unexpected. In comparison to control condition participants, students receiving the metaphor and analog story conditions indicated that the story was more interesting, understandable, engaging, surprising, and more connected to NeoCITIES.

Surprisingly, storytelling did not significantly influence information sharing, team mental models, situation awareness, or team performance. Differences in story types were not salient to participants. One of the reasons why storytelling did not exhibit direct effects on metacognition and performance may have been due to the timing of storytelling. Introduced as part of training, participants may have been overwhelmed with new information, attenuating the effects of the story. In Study 3, we introduced stories after the team had become more familiar with NeoCITIES. Another reason why storytelling did not have more of an impact in this study may have been that participants needed more opportunity to reflect on the stories for them to influence behavior. In Study 3, we explore the interactive effects of storytelling and reflexivity (intervention to allow teams to overtly think about their performance and goals).

Consistent with the results from Study 1, team cognition was found to positively impact team performance, but differential patterns were found depending on specific outcomes. For example, shared temporal team mental models had a positive effect on team performance (percentage of interdependent events completed correctly) when measured as both concept maps ($\beta = 0.26, p < .01$) and paired comparison ratings ($\beta = 0.28, p < .01$). In addition, temporal team mental models operationalized as concept maps and paired comparison ratings accounted for an additional 13% of the variance in team performance (percentage of interdependent events completed correctly) beyond teamwork and taskwork team mental models and controls ($F_{2, 86} = 7.41$, $p < .01$).

Hierarchical regression analyses revealed a significant interaction between shared teamwork and shared temporal team mental models on overall duration (how long it took team members to respond to events) after controls (story conditions, performance at Time 1) and teamwork, taskwork, and temporal team mental model sharedness main effects ($\beta = -0.22, p < .05$; $\Delta R^2 = .05$, $p < .10$). As shown in Figure 6, faster responding teams were on the same page regarding both taskwork and temporal elements of the task. High taskwork sharedness without temporal sharedness was associated with slower response times.

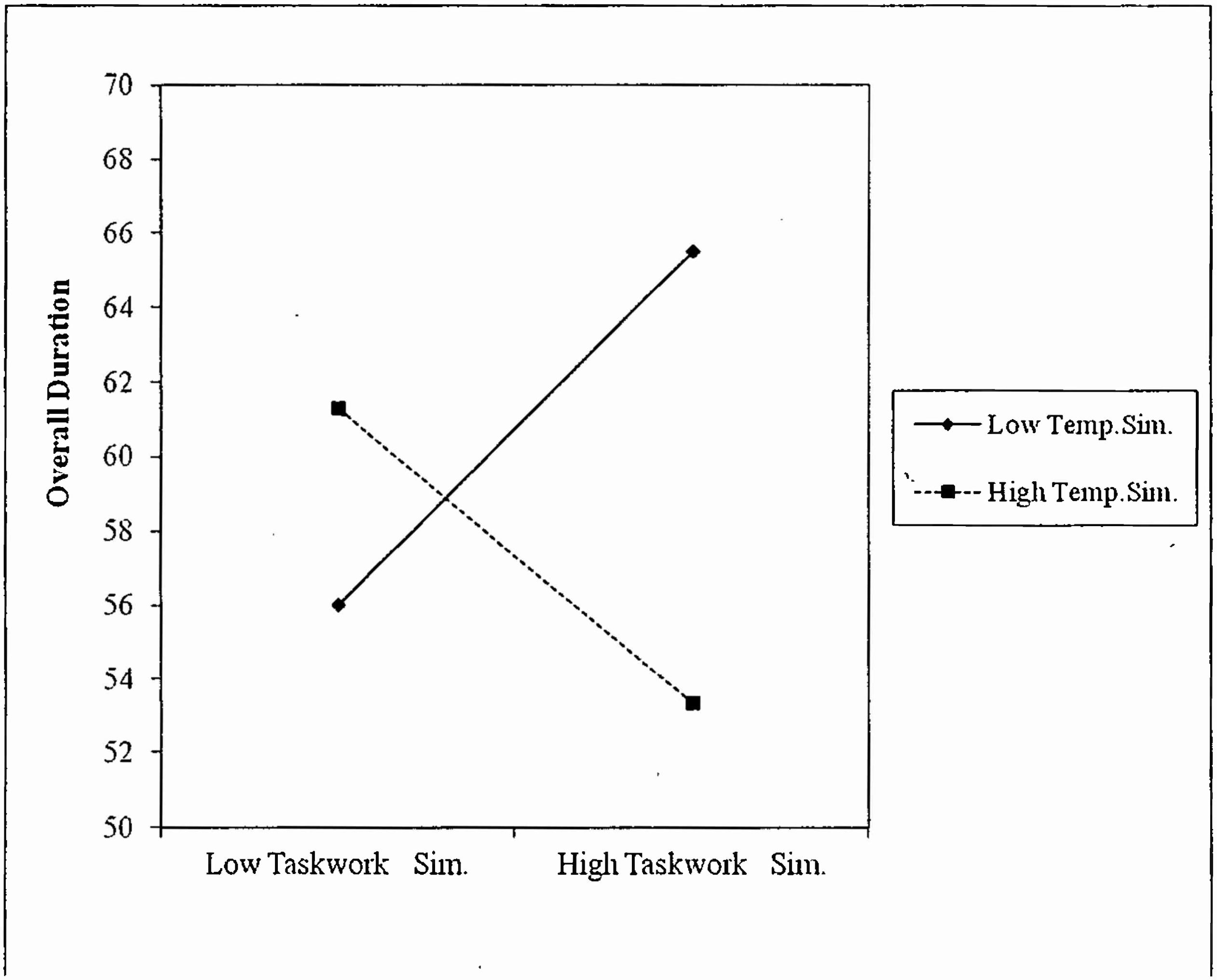

Figure 6: Interaction between Taskwork and Temporal Team Mental Model Sharedness on Overall Team Performance

Hierarchical regression analyses also revealed a significant interaction between concept map and paired comparison rating measures of temporal team mental models on overall team performance ($\beta = -.17, p < .05$; $\Delta R^2 = .025$, $p < .05$). As shown in Figure 7, being low on both temporal team mental model measures lowers performance, but being high on both does not advantage teams. Rather, scoring high on one measure compensates for scoring low on the other measure.

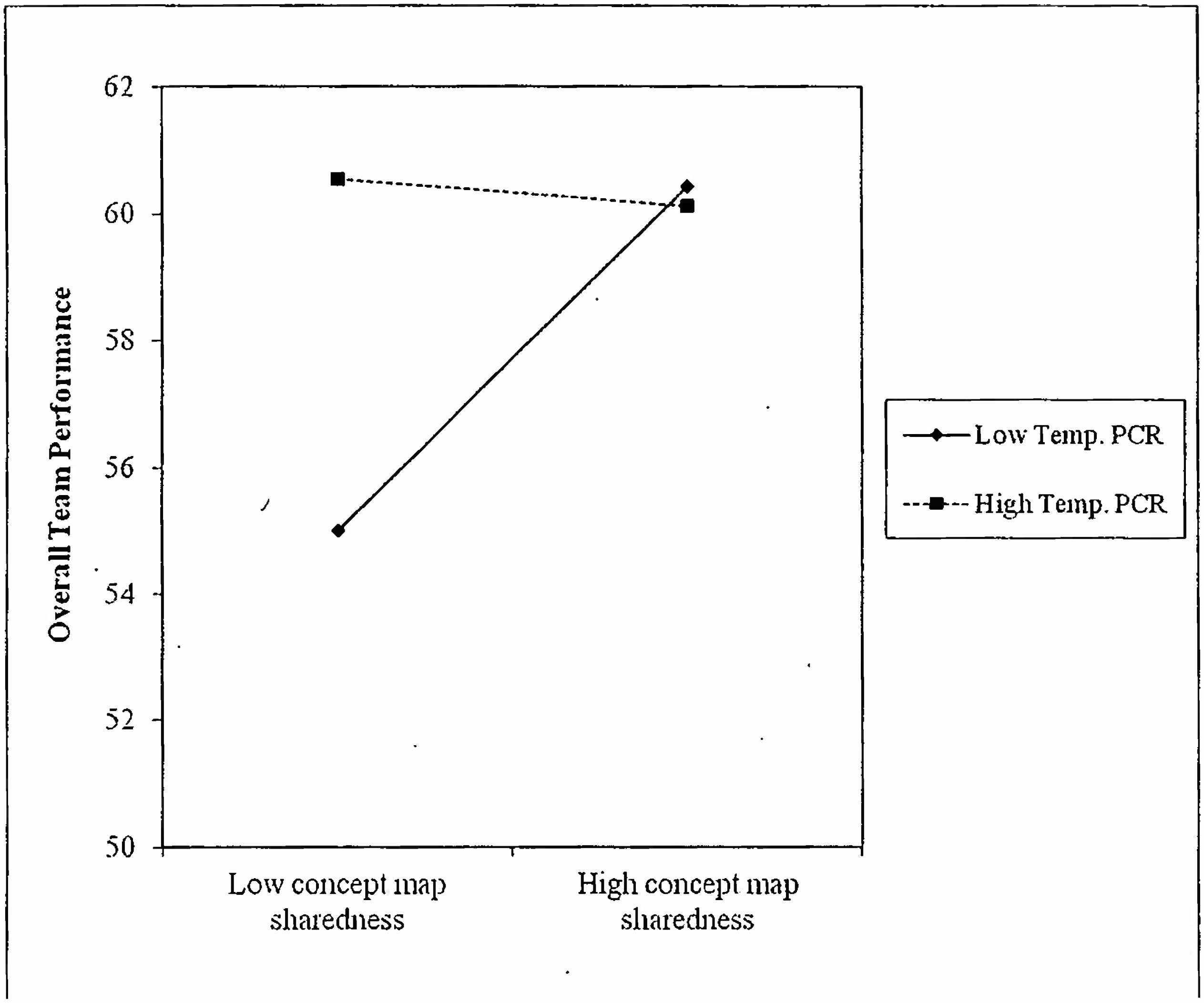

Figure 7: Interaction between Temporal Team Mental Model Sharedness Measured via Concept Maps and via Paired Comparison Ratings on Team Performance

Conclusions

Because anecdotal and conceptual work has dominated the storytelling literature, Study 2 focused on the operationalization of storytelling (as a complex form of metaphor) in team cognition research. Although storytelling has been proposed to be effective in distributed teams, but not empirically verified, we explored the use of storytelling as a team training tool. Contrary to predictions, results revealed that storytelling did not directly affect team cognition or performance. However, several future research directions were outlined in preparation for Study 3.

As in Study 1, we examined team mental models through a more sophisticated lens than previous studies in that taskwork, teamwork, and temporal team mental models were examined and both concept mapping and paired comparison ratings were measured for temporal team mental models. Showing promise for future research, temporal mental models were distinct from taskwork and teamwork mental models and added unique variance beyond these traditional measures. The impact of team mental models on performance was dependent on the type of dependent variable and operationalization assessed.

STUDY 3

Purpose & Overview

The purpose of the third study was to examine storytelling and guided reflexivity as two potential contributors to macrocognitive processes and team performance. Guided reflexivity is a planned intervention to allow teams to overtly reflect on their performance and goals. We furthered empirical examination of storytelling in teams by examining its impact after teams had gained some experience with the NeoCITIES simulation (as opposed to during team training as in Study 2). Some researchers have suggested that stories can be beneficial at any time (Fiore, Johnston, & McDaniel, 2007), while others have proposed that in general, interventions should be made after a team has gained some experience with the task at hand (Gurtner, Tschan, Semmer, & Nagele, 2007; Hackman & Wageman, 2005).

Below is the model examined in Study 3:

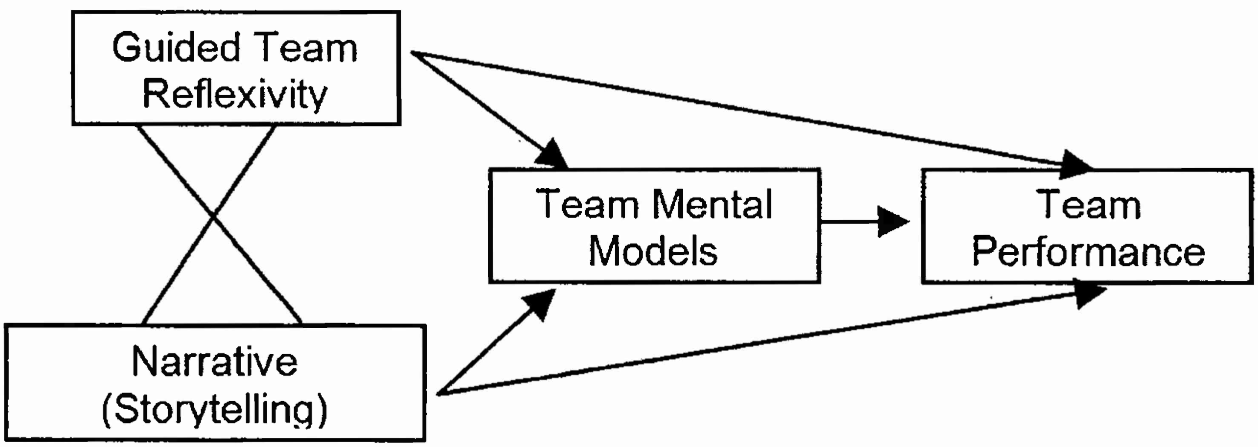

Figure 8: Study 3 Model

Participants

Participants included 321 undergraduate students comprising 107 three-person teams. The sample was 74.1 percent Caucasian and 48.6 percent male. The average age of the sample was 20.62 (SD = 2.33). On a scale of 1 (none) to 5 (extensive), participants reported having little to moderate levels of experience working in a virtual team (mean = 2.23, SD = 1.14).

Experimental Design

The study design was a fully-crossed 2 (storytelling) x 2 (guided team reflexivity) factorial design (see Figure 9 below). The study duration was 2.5 hours.

		Reflexivity	
		Present	None (Control)
Storytelling	Present	X	X
	None (Control)	X	X

Figure 9: The Experimental Design for Study 3

Storytelling Manipulation

Participants viewed a four and a half minute video that told the story of a graduate student who incurred serious health injuries due to a lack of coordination and timing by his emergency response team. A narrator's voice was heard while PowerPoint slides showing pictures and other visual summaries of the key points of the story were displayed. The objective of the story was to convey the message that team members needed to collaborate with each other and time their responses well (i.e., meet deadlines, arrive at events in the proper order) if they were to succeed in their scenario. For the storytelling control groups, the participants viewed a video describing the same objectives of collaboration and timing, but in a non-storytelling format. In order to equalize the time with the storytelling conditions, participants completed a 3.5 minute filler survey and listened to a one minute video explaining the importance of sequencing and meeting deadlines, which was the same as the deep structure of the story condition. In this way, we contrasted the value of a story with just communicating the base information.

In contrast to Study 2, the storytelling manipulation was administered after Scenario 1 instead of as part of training. In addition, only the NeoCITIES timing story was selected from the four stories contrasted in Study 2. Also in contrast to the control condition in Study 2 (similar surface structure, but no deep structure), we communicated the same deep structure as the NeoCITIES simulation.

Reflexivity Manipulation

After the storytelling intervention, participants in the guided team reflexivity condition were given six minutes (based on extensive pilot testing) to reflect on their performance via chat. Three questions were used to guide the discussion, including, "What were the main points you learned from the story that your team can utilize while playing NeoCITIES?", "What went right and wrong in the way your team performed in Scenario 1?", and "Please come up with strategies to improve your performance." In the control group, the participants were told to discuss whether technology was a benefit or detriment to society and interpersonal relationships for an identical amount of time. Piloting revealed that this topic was face valid in terms of relevance to NeoCITIES, but unrelated to strategizing in the simulation.

Experimental Procedure

The addition of the reflexivity condition necessitated increasing the length of Study 3 to 2 and ½ hours. The experimental procedure occurred in the following steps:

- Basic NeoCITIES Training Video & Practice
- Team Training Video & Practice
- Performance Scenario 1 (14 minutes)
    - SAGAT freeze, 1 information briefing
- Online survey
- Storytelling video or control (4.5 minutes)
    - Online manipulation check
- Reflexivity manipulation or control
    - Online manipulation check
- Performance Scenario 2 (15 minutes)
    - SAGAT freeze, 2 information briefings
- Written and online surveys

Results

Storytelling and reflexivity manipulations were effective. All of the hypotheses were tested at the team-level using hierarchical regression. We controlled for video game experience as well as knowledge of, and experience in, emergency response and hospital settings. Specifically, we wanted to ensure that team outcomes were not due to experienced gamers learning the simulation more quickly, or an unfair advantage for participants with greater insight into how emergency events should be solved.

Storytelling was found to have a positive effect on team mental model similarity ($\beta= .251$, $p= .011$). That is, team members who learned the importance of collaboration and timing for successfully playing NeoCITIES via a story had more similar views on how to solve events than team members who were taught the same lessons through a more straightforward, non-story approach.

Guided team reflexivity did not have a significant relationship with team mental model similarity ($\beta= -.004$, ns). That is, simply being given the opportunity to discuss their performance and strategize for the future did not improve teammates' team mental model similarity. However, the interaction of storytelling and reflexivity predicted variance in team mental model similarity above and beyond storytelling alone ($\beta = .197$, $p = .043$). As seen in Figure 10, teams who received a story *and* had an opportunity to reflect on their performance performed the best, while those who only received one or the other (or neither) performed worse. In other words, storytelling may provide the learning content but reflexivity provides the mechanism by which the content can be fully processed. Having a discussion to create strategies and "get on the same page" may not be useful if teammates do not have common knowledge on which to base their discussion.

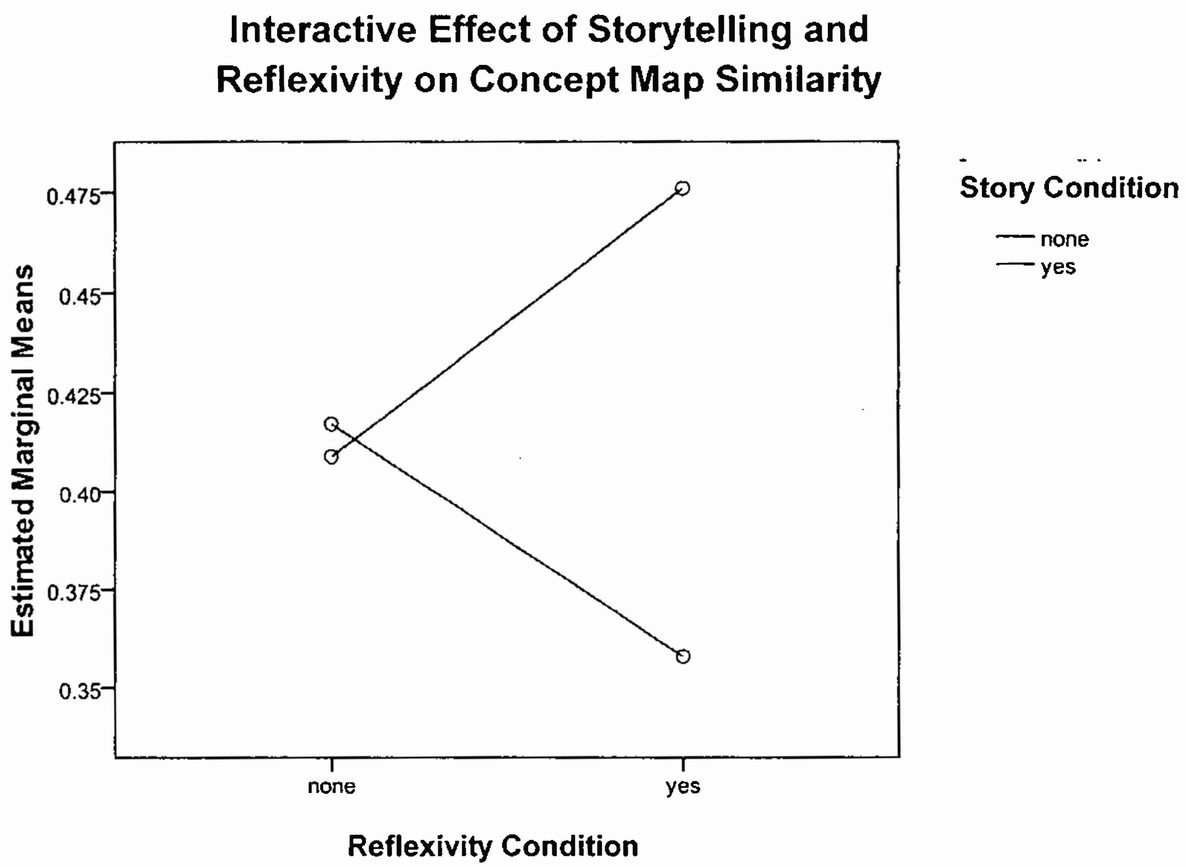

Figure 10: The interactive effect of storytelling and reflexivity on team mental model similarity (concept mapping).

Conclusions

We contributed to the literature by examining two unexplored antecedents of team mental models, which has been identified as a research need in a recent review article (Mohammed et al., 2010). In addition, there has been little empirical examination of reflexivity as a planned team intervention. Results revealed that in the absence of media-rich communication opportunities, the combination of presenting important information in story format and giving team members time to reflect upon their strategies improved team mental model similarity, which in turn improved team performance. For more information about the design, results, and conclusions of Study 3, see Tesler (2011) and Tesler et al. (2011).

STUDY 4

Purpose and Hypotheses

As shown in Study 3, the positive effects of stories and guided team reflexivity on team mental model similarity are enhanced when used in tandem (Tesler et al., 2011). Expanding upon Study 3, the purpose of Study 4 was to further examine the conditions under which storytelling would influence team cognition and team performance. Specifically, we expanded the reflexivity manipulation to compare and contrast individual storytelling reflexivity and group reflexivity conditions. Thus, we investigated the combined effects of three interventions- storytelling, and guided individual and team reflexivity- on team mental model similarity and performance in distributed teams.

Guided individual reflexivity (GIR) occurs when an intervention calls for individual members to reflect on their performance and how they can improve. Guided team reflexivity (GTR) occurs when the intervention is at the group-level, requiring all team members to collectively reflect on their performance and develop strategies for improvement. Although individual reflection may increase one's understanding of what needs to be done and how, there is no guarantee that all team members will derive the same conclusions. Thus, we hypothesized that GTR would be more effective in increasing team mental model similarity than GIR.

Having the opportunity to individually reflect on a story's meaning should allow team members to more efficiently use their knowledge to jointly create strategies for improving future performance. Primed to consider how the lessons from the story could apply to their performance, individual reflexivity participants should more quickly transition the group effort to creating specific performance strategies. However, when the same message is presented in non-story format, individual reflection should be less needed due to the message's straightforward nature. Thus, we hypothesized that the combined presence of GIR and GTR would result in more similar team mental models than GTR alone when a storytelling intervention was also present. We further proposed that team mental model similarity would mediate the relationship between said reflexivity-storytelling interaction and team performance.

Participants & Design

Data was collected from 185 three-person undergraduate teams at a large Mid-Atlantic university. The sample was 68.8 percent Caucasian and 41.4 percent male. The average age of the sample was 20.13 (SD = 1.94). On a scale of 1 (none) to 5 (extensive), participants reported having little to moderate levels of experience working in a virtual team (mean = 1.90, SD = 1.03).

Data was collected on a six-cell experimental design (storytelling/control; individual storytelling reflexivity/control; group reflexivity/control).

The study design was a 2 (storytelling) x 3 (guided individual reflexivity, guided team reflexivity, or both) design with 6 conditions (see Figure 11). Because we were only interested in the relative contributions of GIR and GTR and the effects of reflexivity versus no reflexivity have been supported in prior studies (Tesler, 2011; Tesler et al., 2011), we did not include conditions where neither was present. The study duration was 2.5 hours.

		Guided Reflexivity		
		Individual	Team	Both
Storytelling	Present	X	X	X
	None (Control)	X	X	X

Figure 11: The experiment design, with six conditions.

Storytelling Manipulation

Participants viewed the same five minute video as in Study 3 that told the story of a graduate student who incurred serious health injuries due to a lack of coordination and timing by his emergency response team. A narrator's voice was heard while PowerPoint slides showed pictures and other visual summaries of the key points. The objective of the story was to convey the message that team members needed to collaborate with each other and time their responses well (i.e.; meet deadlines, arrive at events in the proper order) to succeed in their scenarios. For the storytelling control groups, participants viewed a video describing the same objectives of collaboration and timing, but in a non-storytelling format.

GIR Manipulation

After the storytelling intervention, participants in the GIR condition were given an exercise involving matching items from one column (i.e., important elements from the storytelling/control video), to their correct counterparts in the second column (the meanings of those elements as they related to successful performance in NeoCITIES). For example, the item "Police had to clear the roads so that Hazmat could identify the chemical and then Fire could treat Dan" would be matched to "The order in which resources arrive is often important." Thus, participants were given a structured opportunity to make the connections between the story and how it could help improve performance in NeoCITIES. In the control condition, participants were not given any matching task.

GTR Manipulation

Next, participants in the GTR condition were given six minutes (based on extensive pilot testing) to reflect on their performance via chat. Three questions were used to guide the discussion, including, "How well do you think you and your team just performed in Performance Scenario 1?" and "Please come up with strategies to improve your performance." In the control group, participants were told to discuss an unrelated topic on technology and social relationships for an identical amount of time.

Experimental Procedure

The experimental procedure occurred in the following steps:

- Basic NeoCITIES Training Video & Practice
- Team Training Video & Practice
- Performance Scenario 1 (14 minutes)
    - SAGAT freeze, 1 information briefing
- Online survey
- Storytelling video or control (4.5 minutes)
    - Online manipulation check
- Individual Reflexivity manipulation or control
    - Online manipulation check
- Group Reflexivity manipulation or control
    - Online manipulation check
- Performance Scenario 2 (15 minutes)
    - SAGAT freeze, 1 information briefing
- Written and online surveys

Results

Storytelling and reflexivity manipulations were effective. All of the hypotheses were tested at the team-level using hierarchical regression. We controlled for video game experience and knowledge and experience in emergency response and hospital protocols in addition to gender composition (i.e., percentage of females in a team).

Testing the effect of GTR versus GIR on team mental model similarity, we found that GTR indeed had a significantly larger positive effect than GIR on concept map similarity ($\beta = .21$, p<

.05). Therefore, if faced with the choice, a team-level reflexivity intervention will produce members with more similar views on how events should be solved.

When testing whether the positive effects of GTR on team mental model similarity are increased by adding GIR, we found a significant interaction with storytelling ($\beta = -.26$, $p < .01$; Figure 12). Interestingly, simple slope analyses revealed that GTR alone was significantly better at increasing taskwork mental model similarity than GTR and GIR combined in the storytelling condition ($\beta = -.28$, $p < .05$). In fact, storytelling plus GTR had the best outcome overall ($\beta = .16$, $p < .05$). As expected there was no significant difference in the no-story condition ($\beta = .24$, *ns*),

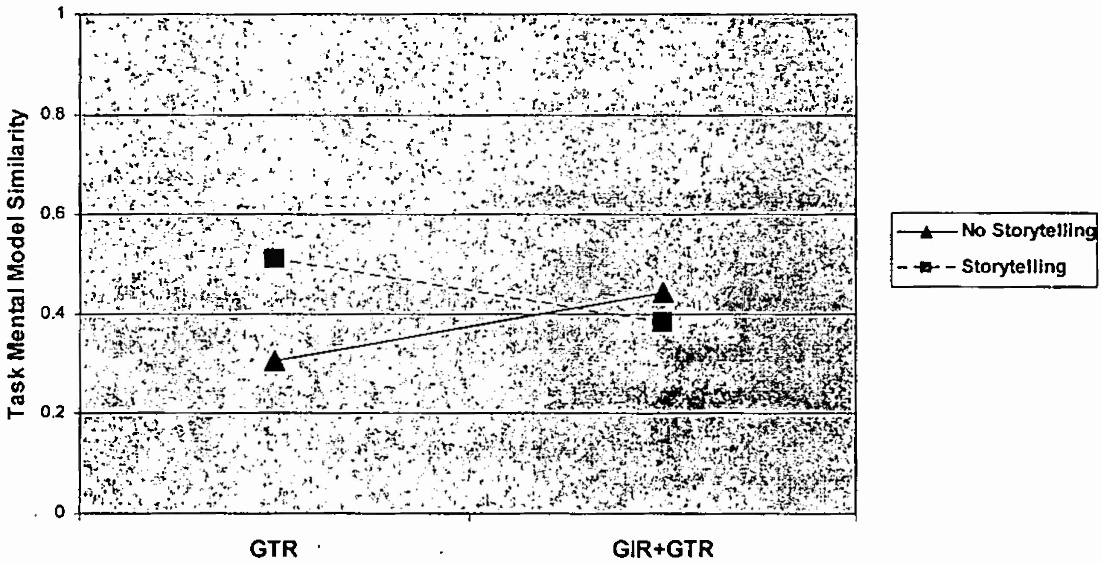

Figure 12: The interactive effect of storytelling and reflexivity on team mental model similarity (similarity ratings).

As expected, we found a significant positive relationship between team mental model similarity and team performance for both concept maps ($\beta = .16$, $p < .05$) and paired comparison ratings ($\beta = .15$, $p < .05$). Utilizing the joint significance test, as recommended by MacKinnon, Lockwood, Hoffman, West, and Sheets (2002), we found support for mediation. Based on the significant relationship between GTR/GIR and concept map similarity, and between concept map similarity and team performance, we concluded that team mental model similarity did mediate the relationship of guided reflexivity type (GTR versus GIR) and performance. Similarly, the significant interaction of reflexivity (GTR/GTR+GIR) and storytelling on taskwork mental model similarity, and the relationship of taskwork mental model similarity with team performance, suggests the presence of moderated mediation.

Conclusions

No study (to our knowledge) has researched the potential additive effects of GIR and GTR on team mental model similarity. While there has been strong support for the effects of team mental model similarity on team performance outcomes (DeChurch & Mesmer-Magnus, 2010a, 2010b), there has not been equal focus on the antecedents of team mental models (Mohammed et al., 2010). Because it is especially important for teams to develop interventions to facilitate shared understanding in the absence of media-rich cues, we examined these relationships in distributed teams.

GTR was found to have a stronger positive effect on team mental model similarity than GIR. That is, being given the opportunity to collectively discuss their performance and strategize for the future improved teammates' team mental model similarity more so than individually reflecting upon a video (regardless of whether containing a story or more straightforward message) that conveyed the importance of collaboration and timing for successfully playing NeoCITIES. Thus, when there is limited time for reflection, group reflexivity is preferable.

When presented with a storytelling intervention, it is preferable to only implement GTR. In fact, results suggest that storytelling plus GTR yield the highest level of team mental model similarity out of all the tested conditions. Adding GIR immediately prior to GTR can actually decrease team mental model similarity. We believed that having the opportunity to individually reflect would allow team members to better connect the story's deep structure learning points to the NeoCITIES simulation in preparation for the group reflexivity session. However, it may be that having the opportunity to engage in GIR resulted in overconfidence in team members' knowledge of how to improve performance, to the point where they did not utilize the GTR intervention to its full potential.

The positive relationships of GTR and the storytelling-reflexivity interaction with team mental model similarity, and the subsequent positive relationship between team mental model similarity and team performance, suggest mediated relationships (MacKinnon et al., 2002). Answering the call for empirical work assessing multiple operationalizations of team mental models in the same study (Mathieu et al, 2005; Mohammed et al., 2010), both concept mapping and similarity ratings were positively related to team performance and evidenced different, but consistent, effects with storytelling and reflexivity. For more information about Study 4, see Tesler et al. (2012).

CONCLUSIONS ACROSS FOUR EXPERIMENTS

This grant project integrated research on *team cognition*, *temporal dynamics*, and *storytelling* towards the goal of improving team coordination and performance in distributed decision making teams.

Across studies, results revealed that various types of team cognition impact multiple team performance indices, demonstrating that macrocognition fosters team effectiveness. Several types of team cognition were positively related to team performance, but results differed depending on the type of team cognition (information sharing, shared situation awareness, team mental models) and the team outcome assessed (overall team performance, timing). We examined team mental models through a more sophisticated lens than previous studies in that taskwork, teamwork, and temporal team mental models were examined and both concept mapping and paired comparison ratings were measured for temporal team mental models. Emphasizing the importance of these design choices, the type of mental model content and operationalization differentially affect team performance.

When team members disagree about deadlines and the pace by which tasks should be completed, coordination and performance problems can result. Therefore, establishing and maintaining congruence in team members' temporal perceptions is a non-trivial task. Infusing a temporal focus into the study of team cognition and team outcomes proved fruitful in better reflecting the time-based context of many organizational and military teams. Showing promise for future research, temporal team mental models were distinct from taskwork and teamwork categories and added unique variance beyond these traditional measures.

Results provided encouraging evidence that storytelling and reflexivity interventions may help overcome the collaborative obstacles faced by team members in distributed environments, particularly when administered at the group level. Storytelling as an intervention did in fact increase team mental model similarity over a non-story format, which in turn increased team performance. However, storytelling is most useful when a team is additionally given an opportunity to discuss and come to a consensus on the story's meaning while developing strategies to improve future performance. Storytelling may provide the learning content but reflexivity provides the mechanism by which the content can be fully processed. In addition, allowing team members to communally reflect upon their performance and strategies is more effective than individual reflection. Furthermore, individual reflexivity does not provide incremental benefits when combined with group reflexivity, and can actually hurt outcomes when storytelling is also present.

SUMMARY OF ACCOMPLISHMENTS

We ventured into non-explored territory on multiple fronts. To our knowledge, we were the first to empirically examine the effect of planned storytelling as a team training intervention as well as to research the potential additive effects of group reflexivity and individual reflexivity on team mental model similarity. In addition, we pioneered the operationalization of a temporal team mental model.

We conducted four programmatic experimental studies (ranging from 71 to 185 three-person teams in each study) examining the impact of multiple interventions (hidden profile task, storytelling, group reflexivity, individual reflexivity) on multiple macrocognition constructs (information sharing, shared situation awareness, team mental models) and team performance.

We developed NeoCITIES 3.0 and the setup of the client server architecture, which was under construction for more than nine months, requiring over 10,000 lines of code and over a month of pilot testing the new interface. NeoCITIES 3.0 allowed for a higher fidelity scoring model and a modern technological infrastructure that implemented a model view controller framework for modular interface. In addition, it allowed for an adaptive interface that was scalable and flexible enough to accommodate new scenario development. In addition, we continued to upgrade and modify NeoCITIES throughout four studies, resulting in the most recent 3.1 version. NeoCITIES 3.0 and 3.1 enabled the empirical investigation of under-researched constructs such as storytelling and temporal mental models as well as integration across macrocognitive concepts such as situational awareness and information sharing. The NeoCITIES 3.1 interface and scenarios can be useful to the future design of C3 systems for ad hoc Navy operations teams.

In terms of output, we produced six publications (two book chapters, four published conference proceedings), fourteen refereed conference presentations, two master's theses, and one dissertation. One manuscript is currently under review with others in preparation. Conference presentations were made to the Society of Industrial/Organizational Psychology, Academy of Management, Human Factors and Ergonomics Society, Interdisciplinary Network of Group Researchers, and the International Science of Team Science. One of the presentations was featured as a top-rated poster at the 2011 Society for Industrial/Organizational Psychology annual conference and a finalist for the best student submission award. The Appendix contains a listing of grant output.

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Appendix: ONR Grant Output

Publications

Under Review

- Mancuso, V., Hamilton, K., Tesler, R., Mohammed, S., & McNeese. M. An experimental evaluation of the effectiveness of endogenous and exogenous fantasy in computer-based simulation training (under review at *Simulation and Gaming*).

Chapters

- Mohammed, S., Tesler, R., & Hamilton, K. (2012). Time and shared cognition: Towards greater integration of temporal dynamics. In E. Salas, S. Fiore, & M. Letsky (Eds.), *Theories of Team Cognition: Cross Disciplinary Perspectives* (pp. 87-116). New York: Taylor and Francis Group, LLC.
- McNeese, M. & Pfaff , M. (2012). *Looking at macrocognition through an interdisciplinary, emergent research nexus.* In E. Salas, S. Fiore, & M. Letsky (Eds.), *Theories of Team Cognition: Cross Disciplinary Perspectives* (pp. 345-371). New York: Taylor and Francis Group, LLC.

Published Conference Proceedings

- Hamilton, K., Mancuso, V., Minotra, D., Hoult, R., Mohammed, S., Parr, A., Dubey, G., MacMillan, E., & McNeese, M. (2010). Using the NeoCITIES 3.1 simulation to study and measure team cognition. *Proceedings of the 54th Annual Meeting of the Human Factors and Ergonomics Society* (pp. 433-437). San Francisco, CA: Human Factors and Ergonomics Society.
- Hellar, D.B., & McNeese, M. (2010). NeoCITIES: A simulated command and control task environment for experimental research. *Proceedings of the 54th Meeting of the Human Factors and Ergonomics Society* (pp. 1027-1031). San Francisco, CA.
- Mancuso, V., Parr, A., McMillan, E., Tesler, R., McNeese, M., Hamilton, K., & Mohammed, S. (2011). Once upon a time: Behavioral, affective and cognitive effects of metaphorical storytelling as a training intervention. *Proceedings of the 55th Annual Meeting of the Human Factors and Ergonomics Society* (2113-2117). Las Vegas, Nevada: Human Factors and Ergonomics Society.
- Mancuso, V., Hamilton, K., McMillan, E., Tesler, R., Mohammed, S., & McNeese, M. (2011). What's on "their" mind: Evaluating collaborative systems using team mental models. *Proceedings of the 55th Annual Meeting of the Human Factors and Ergonomics Society* (1284-1288). Las Vegas, Nevada: Human Factors and Ergonomics Society.

Refereed Conference Presentations

- Mohammed, S. (October, 2008). Time and team mental models: Towards greater integration of temporal dynamics. Presentation given to a workshop entitled, "Developing

Multi-Disciplinary Theories and Frameworks of Shared Cognition" jointly sponsored by the University of Central Florida and the Office of Naval Research, Orlando, FL.

- McNeese, M., Hellar, B., Mohammed, S., & Hamilton, K. (April, 2009). NeoCITIES: A game for team cognition and collaborative technology study. In W. Bedwell (Chair), Research on teams and multi-team systems: Selecting game-based research platforms. A symposium presented to the Twenty-Fourth Annual Conference of the Society for Industrial/Organizational Psychology, New Orleans, LA.
- Mohammed, S., Hoult, R., Hamilton, K., Minotra, D., Hellar, B., & McNeese, M. (July, 2009). Time and Shared Cognition: Towards Greater Integration of Temporal Dynamics. In R. Rico (Chair), New trends in team coordination: Knowledge, understanding, timing, and structure. A symposium submitted to the Fourth Annual Interdisciplinary Network for Group Research (INGRoup) conference, Colorado Springs, CO.
- Hamilton, Mohammed, Mancuso, Hoult, Minotra, & McNeese. (July, 2010). It's about time: the conceptualization and operationalization of temporal team mental models. A paper presented to the Fifth Annual meeting of the Interdisciplinary Network of Group Researchers (INGRoup), Washington, DC.
- Mohammed, S., Hamilton, K., Hoult, R., Mancuso, V., Minotra, D., & McNeese, M. (August, 2010). The treatment of time in team mental model research. In M. Shuffler & E. Salas (Chairs), It's about time! Emerging trends in temporal research across multiple levels. A symposium presented to the 70th annual meeting of the Academy of Management Conference, Montreal, Quebec, Canada.
- Hamilton, K., Mancuso, V., Minotra, D., Hoult, R., Mohammed, S., McNeese, M., Parr, A., Dubey, G., & MacMillan, E. (September, 2010). Using the NeoCITIES 3.1 simulation to study and measure team cognition. A paper presented to the 54th annual meeting of the Human Factors and Ergonomics Society, San Francisco, CA.
- Hellar, D.B., & McNeese, M. (September, 2010). NeoCITIES: A simulated command and control task environment for experimental research. A paper presented to the 54th Meeting of the Human Factors and Ergonomics Society, San Francisco, CA.
- Tesler, R., Mohammed, S., Hamilton, K., Mancuso, V., Parr, A., MacMillan, E., & McNeese, M. (April, 2011). The effects of storytelling and reflexivity on team mental models. A poster presented to the Twenty-Sixth Annual Conference of the Society for Industrial/Organizational Psychology, Chicago, IL.
- Hamilton, K., Mohammed, S., Mancuso, V., Tesler, R. M., & McNeese, M. D. (April, 2012). Virtual team effectiveness: Effects of temporal team mental models. In T.M. Nielsen (Chair), Virtual teams: Exploring new directions in research and practice. A symposium presented to the Twenty-Seventh Annual Conference of the Society for Industrial/Organizational Psychology, San Diego, CA.
- Mancuso, V., Parr, A., McMillan, E., Tesler, R., McNeese, M., Hamilton, K., & Mohammed, S. (September, 2011). Once upon a time: Behavioral, affective and cognitive effects of metaphorical storytelling as a training intervention. A paper presented to the 55th annual meeting of the Human Factors and Ergonomics Society, Las Vegas, Nevada.
- Mancuso, V., Hamilton, K., McMillan, E., Tesler, R., Mohammed, S., & McNeese, M. (September, 2011). What's on "their" mind: Evaluating collaborative systems using team mental models. A paper presented to the 55th annual meeting of the Human Factors and Ergonomics Society, Las Vegas, Nevada.

- Tesler, R. M., Mohammed, S., Mancuso, V., Hamilton, K., & McNeese, M. D. (April, 2012). Improving team mental models: Individual versus team reflexivity and storytelling. A poster presented to the Twenty-Seventh Annual Conference of the Society for Industrial/Organizational Psychology, San Diego, CA.
- Hamilton, K., Mancuso, V., Tesler, R., Mohammed, S., & McNeese, M. (April, 2012). Process versus product: The effect of team situation knowledge on team performance. A poster presented to the Third Annual International Science of Team Science Conference, Chicago, IL.
- Mohammed, S., Hamilton, K., Tesler, R., Mancuso, V., Parr, A., & McNeese, M. (April, 2012). It's time: Temporal explorations of team cognition and team outcomes. A poster presented to the Third Annual International Science of Team Science Conference, Chicago, IL.

List of the Conferences in Which Our Work Has Been Presented:

- Society for Industrial/Organizational Psychology
- Academy of Management
- Human Factors and Ergonomics Society
- Interdisciplinary Network of Group Researchers (INGRoup)
- International Science of Team Science

Awards

Tesler, R., Mohammed, S., Hamilton, K., Mancuso, V., Parr, A., MacMillan, E., & McNeese, M. (April, 2011). The effects of storytelling and reflexivity on team mental models. A poster presented to the Twenty-Sixth Annual Conference of the Society for Industrial/Organizational Psychology, Chicago, IL.

- **Featured as a Top-Rated Poster for 2011*
- **Finalist for the John Flanagan Award given for the most outstanding student contribution to the SIOP conference program*

Master's Theses

- Mancuso, V. (2010). *Forming effective transactive memory systems in distributed teams.* Unpublished Master's thesis, The Pennsylvania State University, University Park.
- Tesler, R. (2011). *The effects of storytelling and reflexivity on team mental models in distributed decision making teams.* Unpublished Master's thesis, The Pennsylvania State University, University Park.

Dissertations

- Hellar, D. B. (2009). *An investigation of data overload in team-based distributed cognition systems.* Unpublished doctoral dissertation, The Pennsylvania State University, University Park.